

Proton Source: Linac and Booster

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AAC Review
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Talk Outline



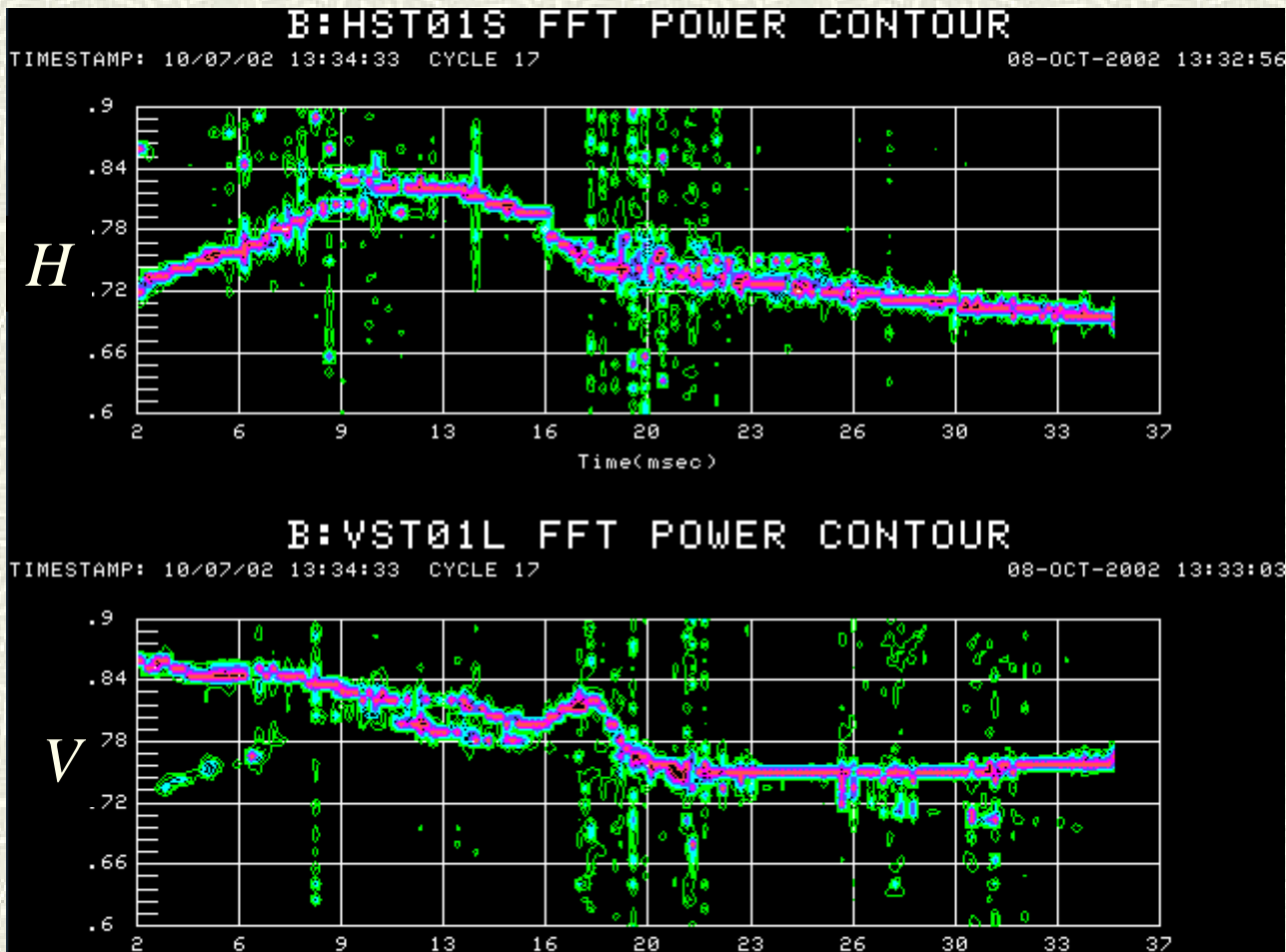
- # Improvements made since last June.
- # Current operational performance.
 - *Beam parameters.*
- # Current issues:
 - *Operational.*
 - *Technical.*
 - *Physics.*
 - *Administrative.*
- # Plans and expectations for the next 8 months.

Improvements Since June, 2002



- # Linac 201 MHz Modulator “Switch Tube” inventory (61 tubes) tested
 - *One tube rebuilt successfully by Econco.*
- # Tevatron Clock: Trailer hitch mode for adding MiniBooNE pulses
 - *Full flexibility in added MiniBooNE pulses to TCLK.*
- # Replaced Booster’s MP02 extraction magnet & power supply
 - *No hardware limits for running at 5 Hz*
- # Upgrade of Linac water systems (200 MHz)
- # Booster tune measurement through cycle 



Booster Tunes Through Cycle



Time in Booster cycle, milliseconds

Improvements, Continued



- # MiniBooNE: $4E12$ protons/pulse at 1 Hz
- # Booster vacuum controls upgrade underway
- # Longitudinal dampers work ongoing
 - *Dedicated cavity commissioned*
- # Booster Collimators
 - *New plan is underway*
 - Project Manager: *Kasper*
 - *Expect to install by July shutdown*
 - *2X improvement in flux?*
- # Ion Profile Monitor (IPM) operational 
- # Significant improvements in personnel deficit 

Calibrating the Booster Ionization Profile Monitor: Preliminary Summary

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FNAL

and

G. Jungman

LANL

January 28, 2003

Abstract

We have performed a calibration of the Booster Ionization Profile Monitor (IPM) using a new model of the ion dynamics in the detector and independent measurements of the beam width. We obtain the formula

$$\sigma_{measured} = \sigma_{beam} + C_1 N \sigma^{p_1},$$

where N is the current in units of 10^{12} , $C_1 = (1.13 \pm 0.06) \times 10^{-5} \text{m}^{1-p_1} / 10^{12}$, and $p_1 = 0.615 \pm 0.013$.

1 Device Description

The Booster IPM measures beam profiles using ions produced by the beam from the imperfect vacuum of the machine. An applied transverse clearing field causes the ions to drift to a Micro Channel Plate (MCP). The beam direction defines the longitudinal coordinate[1]. The detector is 0.5 m long, with a transverse gap of 12 cm. The MCP plate is $8 \times 10 \text{ cm}^2$ and has strip spacing 1.5 mm. The clearing field is 8 kV.

2 Theoretical Calculation

We start by considering the scattering of particles in a gaussian beam by the beam itself as well as an applied electric field. The total force felt by an ion in the combined field is

$$\vec{F} = \hat{r} \frac{a}{r} (1 - \exp(-r^2/2\sigma^2)) + b\hat{x}$$

Personnel Changes!!



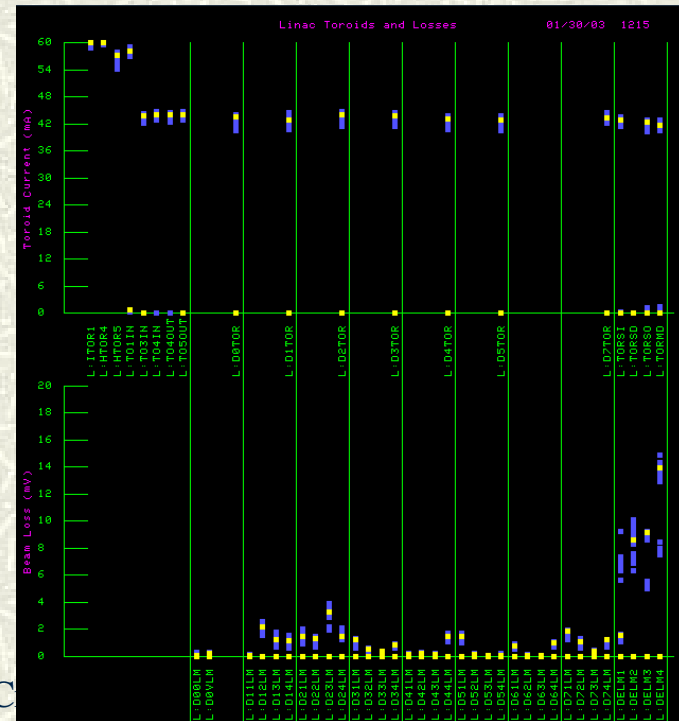
- # Chuck Ankenbrandt (1/1/03) has transferred to Booster as “Beam Physics Liaison,” charged with prioritizing studies.
 - # Craig Drennan (1/1/03) has transferred to Booster to assist and to take over engineering duties with/from Bill Pellico (~replaces Bob Webber).
 - # Tom Dombeck (10/1/02) has transferred to Booster to help with physics and administrative duties.
 - # Trevor Butler (6/15/02) has been hired to perform engineering duties for Linac.
 - # Yang Xi (postdoc) will soon join group (2/15/03?), primarily working on non-invasive, laser-based profile measurement. Will work for Chuck *and* for NICADD (Court Bohn).
-
- # Xiaobiao Huang (graduate student) will come up from Indiana to work on precision lattice measurement and study mechanisms of beam loss from space charge. *Volunteer*
 - # Linda Coney (postdoc) has begun to contribute significant time. Primarily working on beam steering and lattice measurement. *Volunteer*
 - # Larry Bartoszek has been commissioned, through the efforts of the MiniBooNE collaboration, to assist in designing the collimator shielding.

Current Operational Performance



- # The Proton Source does not limit Run II Operations
 - *But MiniBooNE demands lead to compromises*

- # Current Linac performance
 - *43-45 mA at up to 4 Hz*
 - *NTF operates 3 times/week*
 - *MuCool Annex construction*



Proton Source Parameters

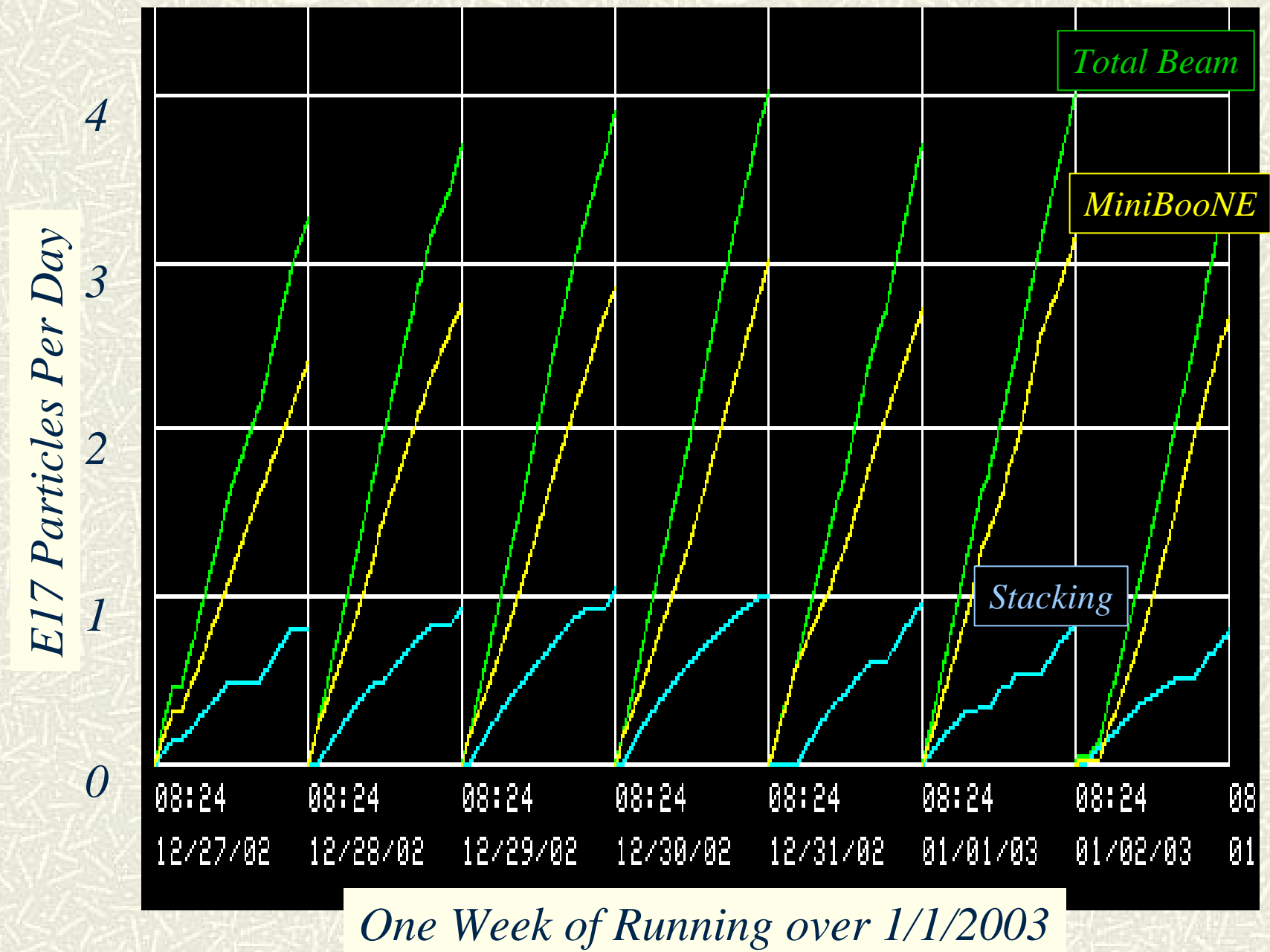


Parameter	Current Performance	Run II Handbook Goal	Comments
Pbar Stacking Pulse Intensity	4.5E12/batch = 5.5E10/bunch	>5E12/batch	Limited by Booster efficiency and residual radiation concerns
Hourly Intensity	0.8E16 Run II	1.2E16	Limited by Pbar cooling cycle time
Transverse Emittance	15-17 π mm-mr	<15 π mm-mr	
Collider filling Intensity	7 bunches @ 5.5 - 5.9E10 / bunch	5-7 bunches @ 6E10 / bunch	
Longitudinal Emittance	0.1 - 0.15 eV-sec / bunch	<0.1 eV-sec / bunch	Better understanding of transition crossing & improved long'l dampers
MiniBooNE Intensity	4.0E12/batch @ 1 Hz = 1.4E16 pph	8E16 pph	Residual radiation issues

Current Booster Performance



- # Collider: $4.5E12$ protons per pulse at (1/2.2) Hz.
 - *Approximately satisfying their demands.*
 - *Can provide $5E12$ ppp, but reducing this to accommodate more flux for MiniBooNE.*
- # MiniBooNE: $4.0E12$ ppp at 1 Hz ($1.4E16$ pph)
 - *Only 20% of desired $8E16$ pph*



Operational Limitations



Linac

- *Inventory of 200 MHz power amplifiers (Burle “7835”) still an issue*
 - Situation has not affected operations, yet
 - # of spares has not increased
 - Three of last 11 tubes failed prematurely
 - *Expect/need 11,000 hours, got: 2664, 5469 and 6410 hours*




Booster & Linac: Losses & Activation



Limitations: Losses/Activation



Linac

- *Activation is noticeable, but not a limiting factor* 
- *Tunnel shielding a problem at flux \rightarrow 5X higher*

Booster

- *Booster losses increase non-linearly above $\sim 4E12$ ppp* 
 - Can run $4.8E12$ (and higher), but leads to unacceptable activation
- *Activation already limiting maintenance*
 - RF15: >200 mR/hr at one foot 
 - Average activation in Booster tunnel is ~ 10 mR/hr
- *Component damage*
 - Cable failures seen already
 - Extraction kicker failed 1/28/2003, probably from radiation damage

Activation decays, roughly, as $e^{-a t [days]}$

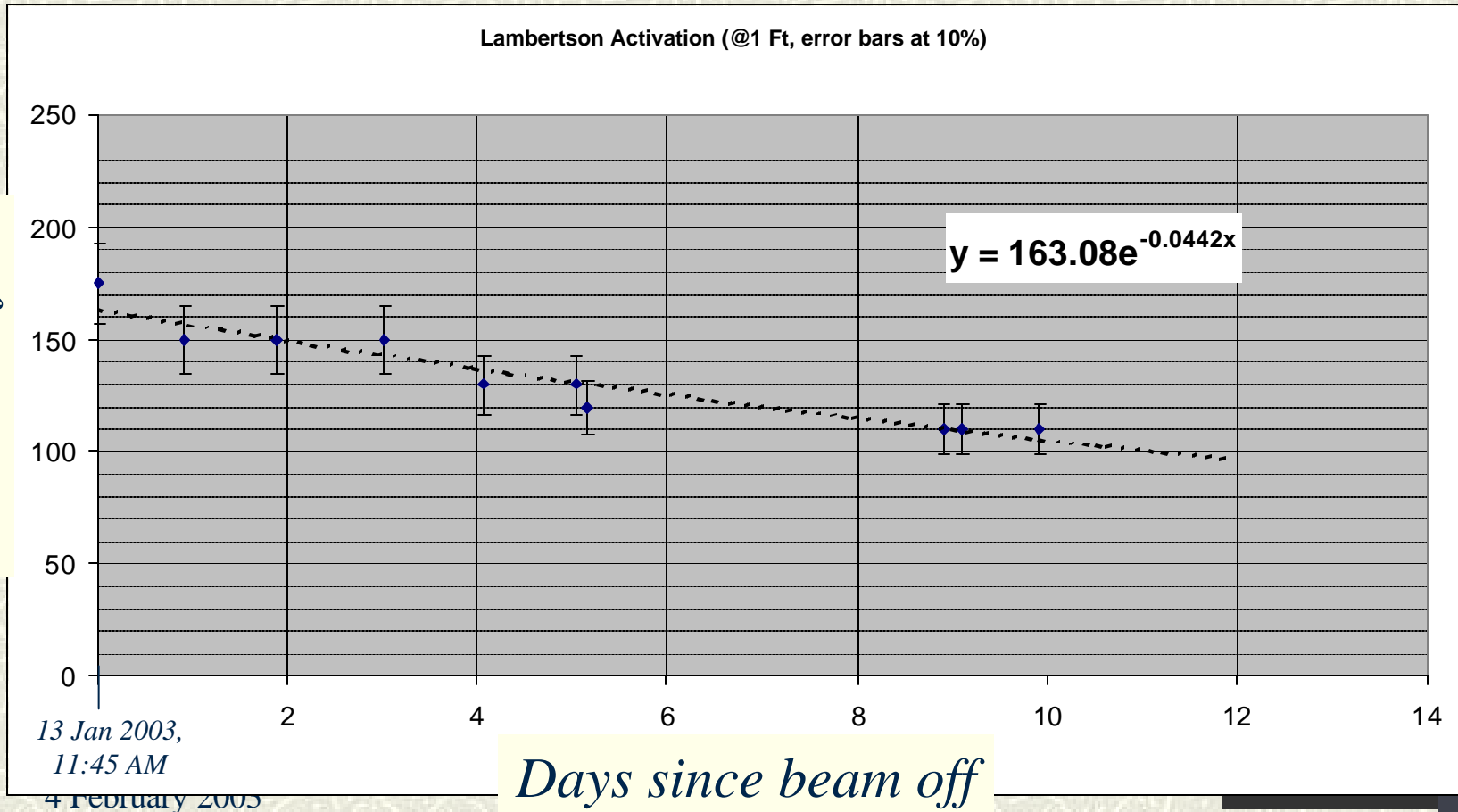
- $0.03 < a < 0.05$
- *Half-life: 15-20 days*

Activation Decay of Linac 400 MeV Lambertson

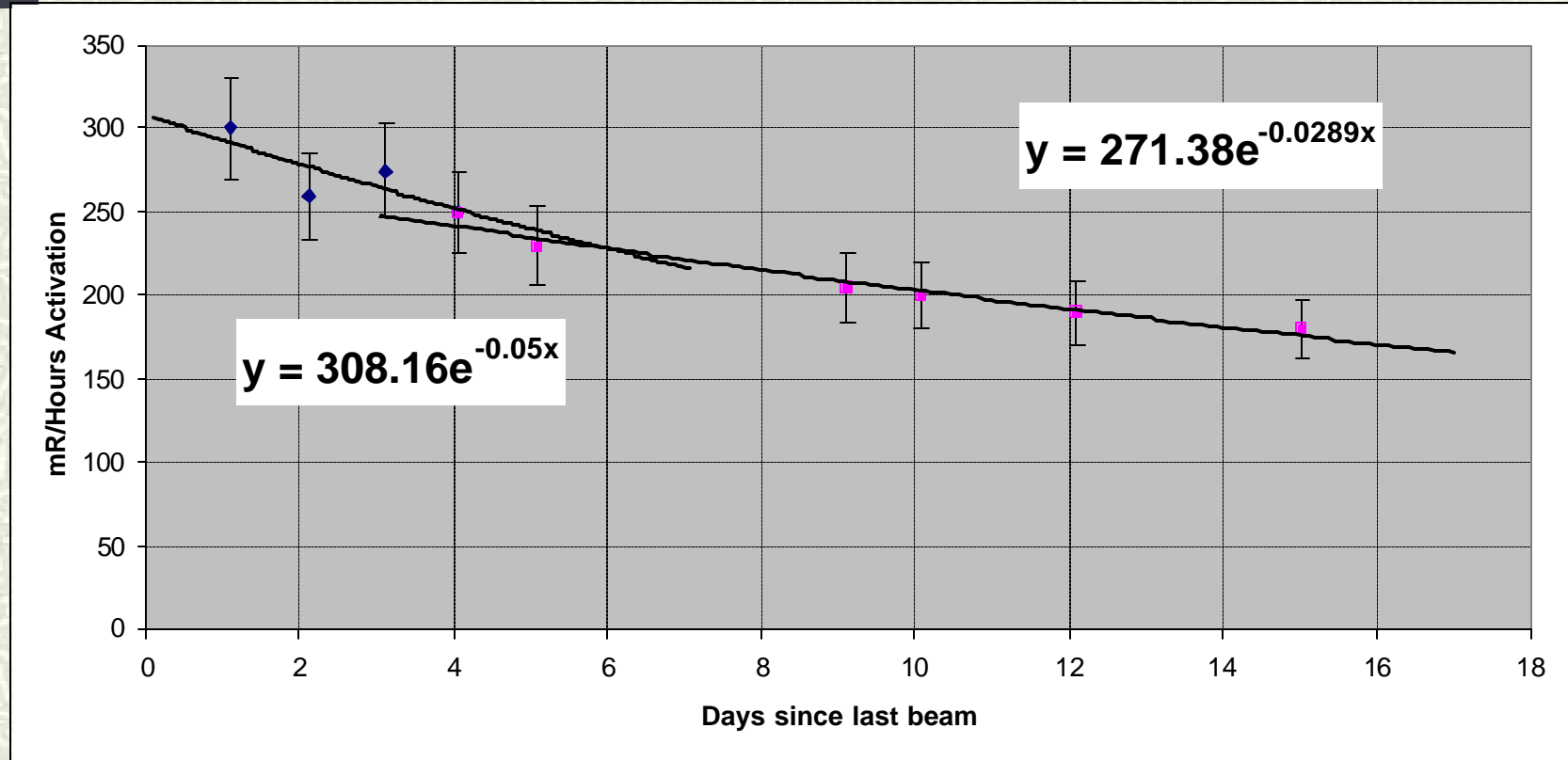


⌘ Slated for replacement in July shutdown

mR/hr at 1 foot



Activation of Booster RF Station 15

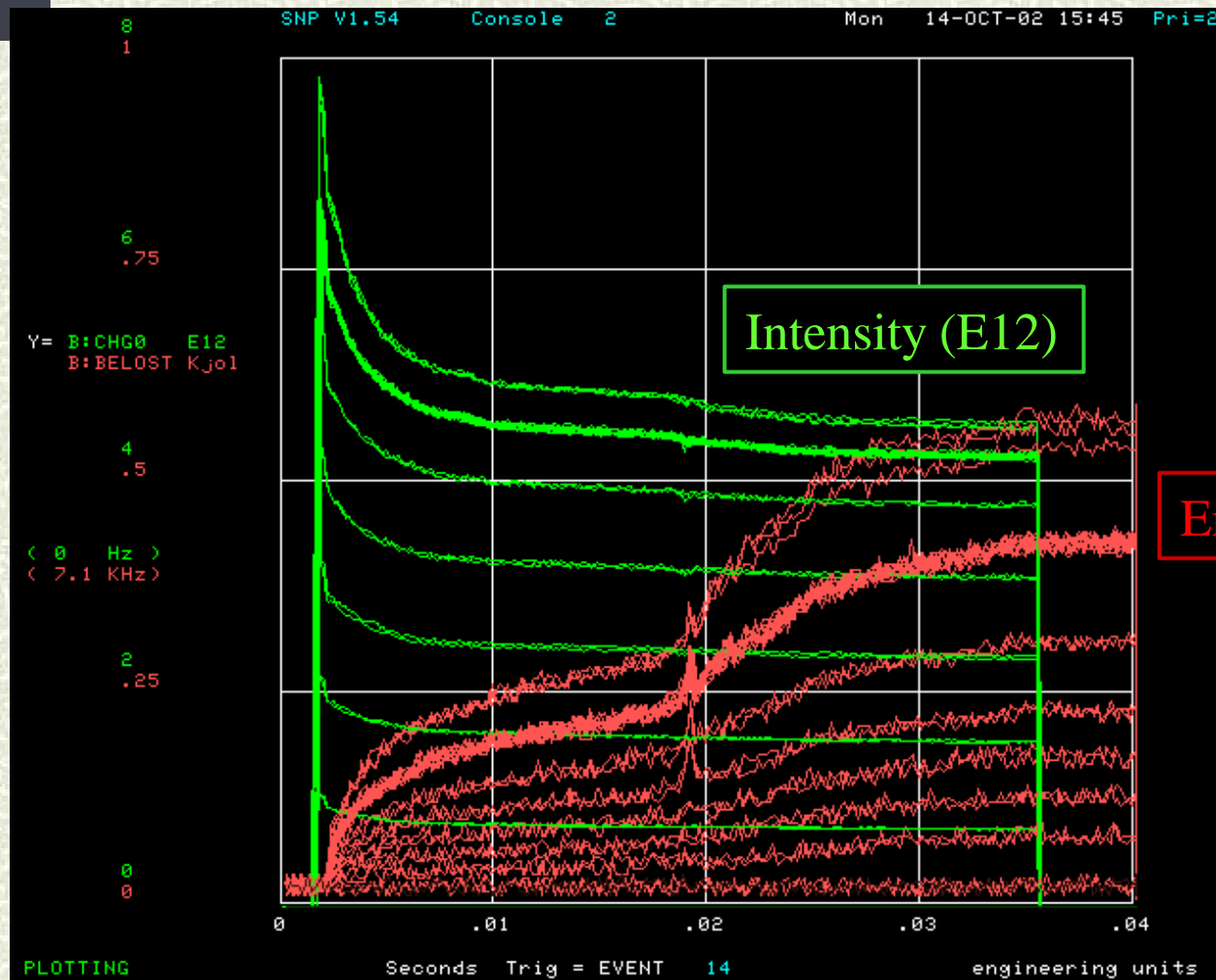


■ An improvement since November

→ *Changed this PA last week*



■ *We reduced beam to MiniBooNE*

Booster Losses vs. Intensity

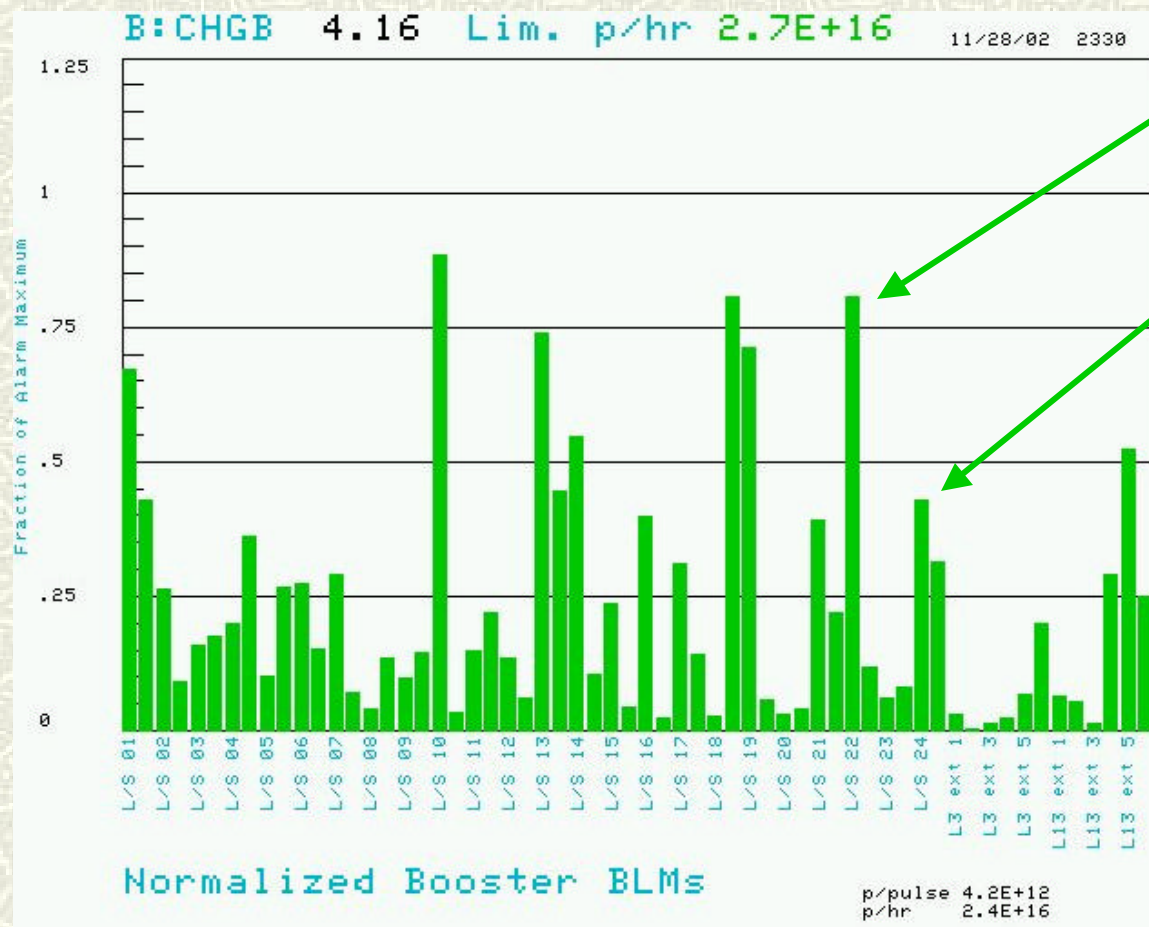


Trips Points Added to Contain Losses



- # ~Dozens loss monitors with trip levels set to reduce activation 
 - *Not completely adequate!*
- # Average power lost: B : BPL5MA 
 - *Equals: $\langle [d/dt (I_{\text{Booster}}(t))] * E(t) \rangle_{(5 \text{ minutes})}$*
 - *Limit: 400 Watts*
 - *Also not completely adequate!*

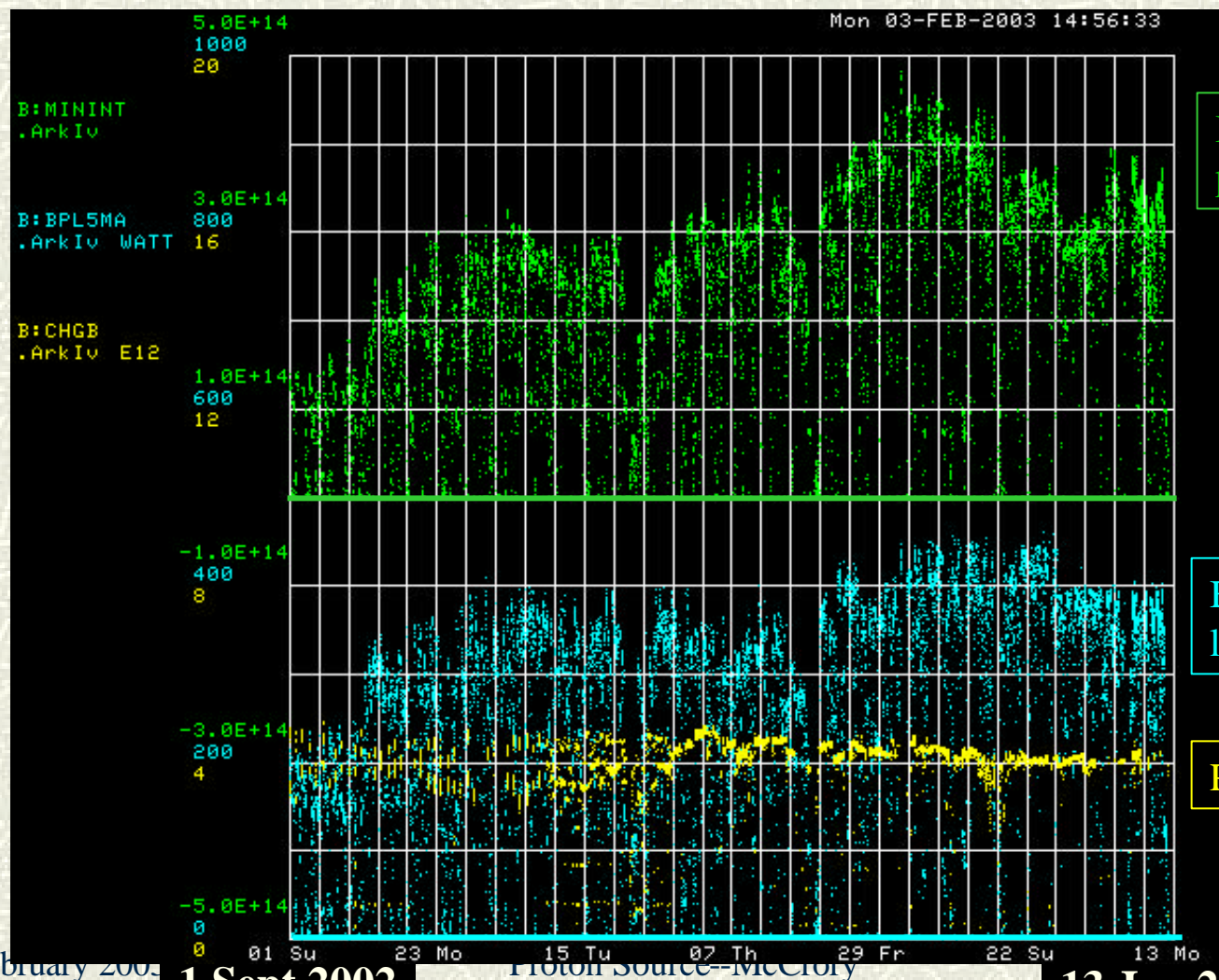
Loss Monitor Trip Points



BRF11: 200 mR/hr @ 1ft

BRF15: 300 mR/hr @ 1ft

Power Lost in Booster



Beam extracted
per minute, E14

Beam power
lost, watts

PPP, E12


4 February 2003

1 Sept 2002

13 Jan 2003

Current Issues: Technical (1/3)

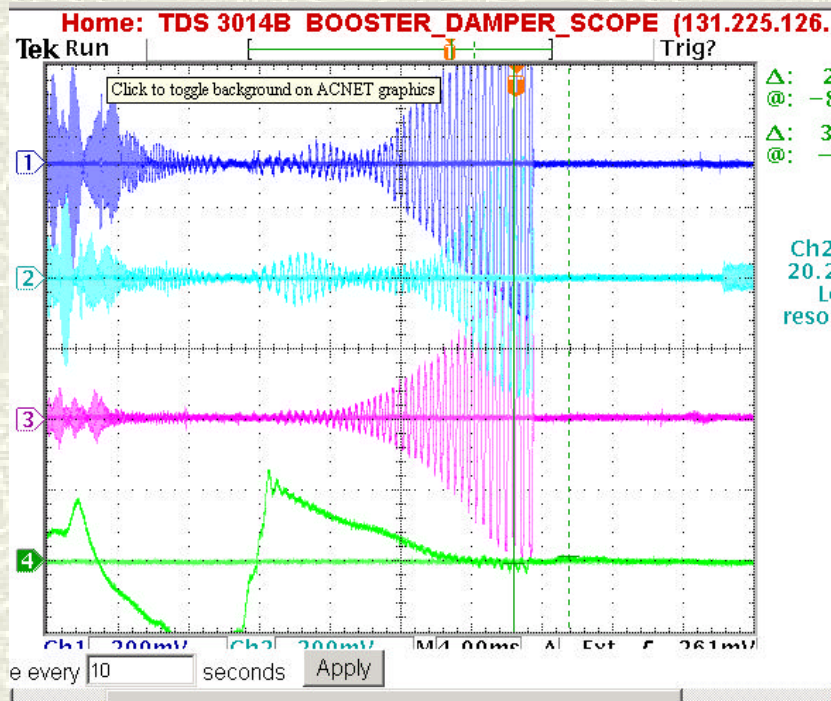


- # Goal: Reduction of losses at higher ppp levels
- # Longitudinal dampers 
 - *Work is ongoing, Pellico*
- # Transition jump system
 - *Tried ~1.5 years ago, but failed due to longitudinal instabilities and misaligned quads*
 - *Re-commissioning now*

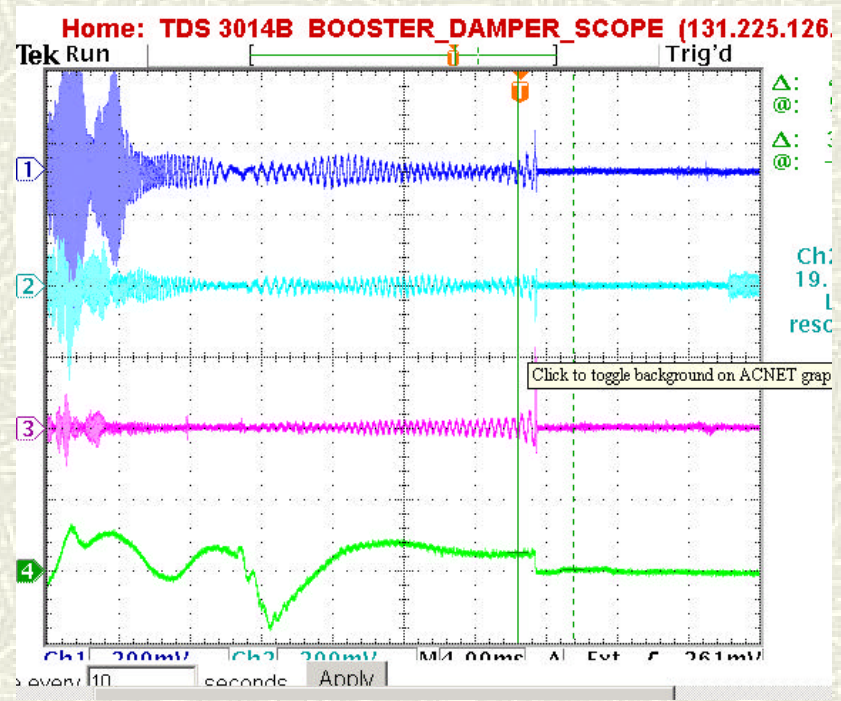
Booster Longitudinal Dampers



No Dampers




Dampers Working



Technical Issues, Continued (2/3)



- # Ramp monitor program 
 - *Under development, in Java, Guglielmo (CD)*
- # Aperture and Orbit Improvements
 - *Ramped correctors, Prebys*
- # RF cavity upgrade
 - *Increase aperture from 2¼" to 5"*
 - *Entire project is very expensive*
 - *Universities will machine parts for two prototype cavities of new design*
 - *Project manager assigned: Padilla*
 - First assignment: Can prototypes be installed in August?

Ramp Monitor Program



Latest Measurement

1 sigma envelope





Technical Issues, Continued (3/3)



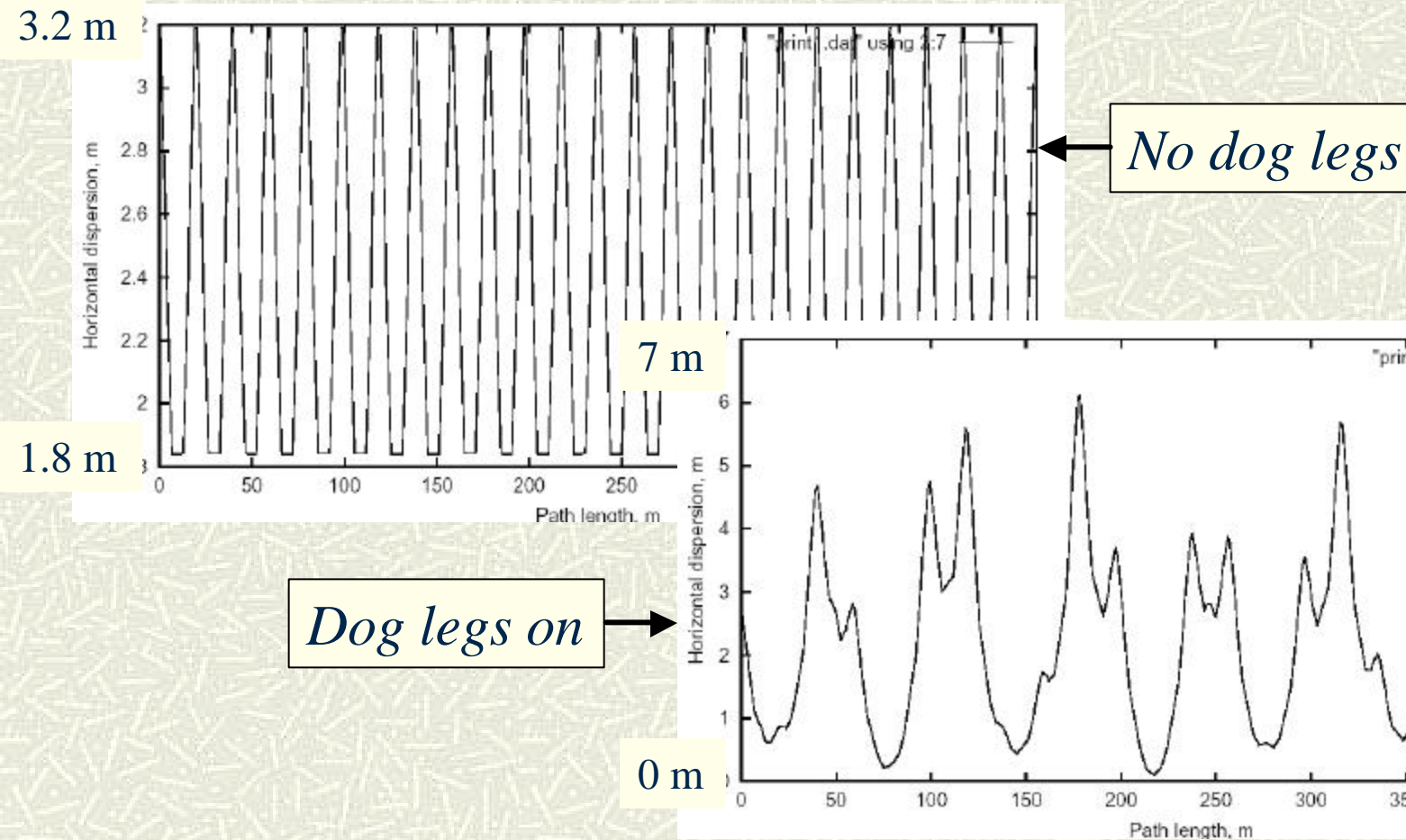
- # LLRF improvements
- # Longitudinal dampers improvements
- # Phase lock improvements to MI
 - *Attempt phase lock of beam signal rather than VCO signal to MI RF reference*
- # Injection overhaul
- # Maintaining traditional reliability
- # NUMI turn-on is coming ...

Current Issues: Physics

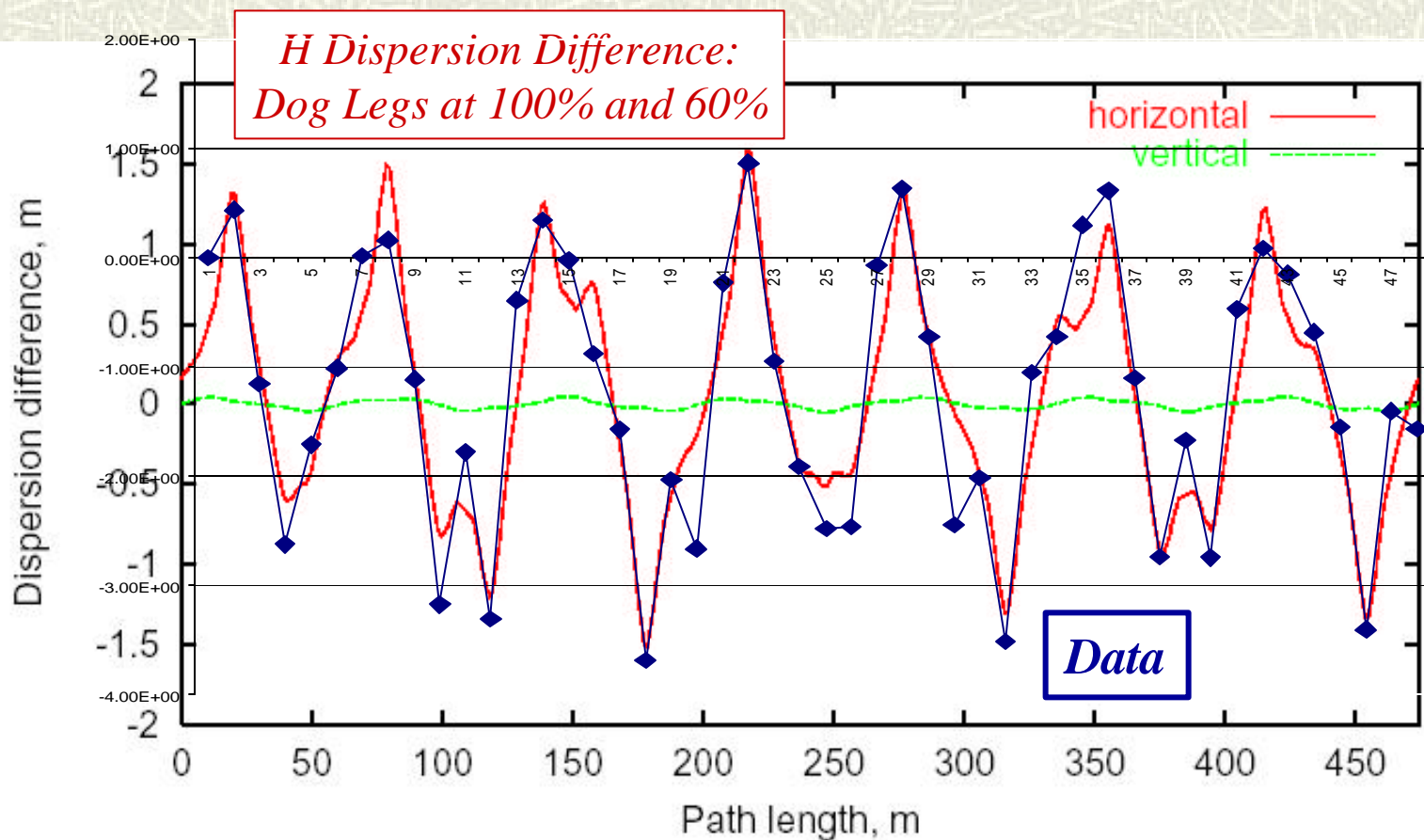


- # Space-charge study group requesting studies
 - *Many participants: BD/Physics (Chou, Spentzouris, Ostiguy), NICADD (Bohn + students & post-docs), NUMI/MINOS (various), MiniBooNE (various)*
- # Ion Profile Monitors
 - *Spentzouris, Amundsun, Jungman, Tomlin, Prebys, etc.*
 - *Understanding the calibration*
- # Lattice calculations   
 - *Drozhdin, et al.*
 - *Dispersion problems at injection*
 - Caused by injection “OrBump” and the “dog legs” around extraction septum
 - Verified by studies last week
- # Minimum configuration for Collimator Shielding 
 - *Kasper, Prebys, Mohkov, Bartoszek, Chen, etc.*

Edge Effects of Dog Legs on Dispersion: Predicted



Edge Effects from Dog Legs

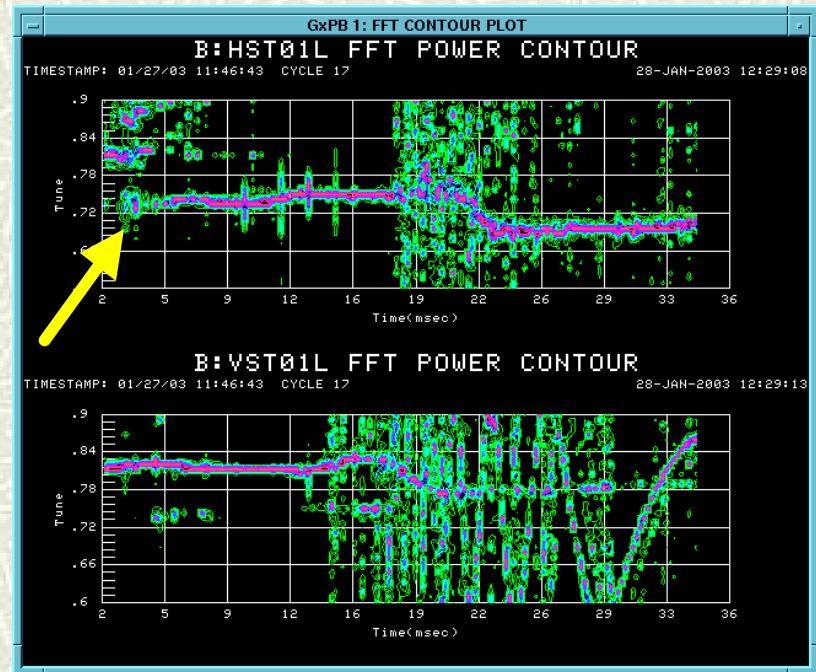
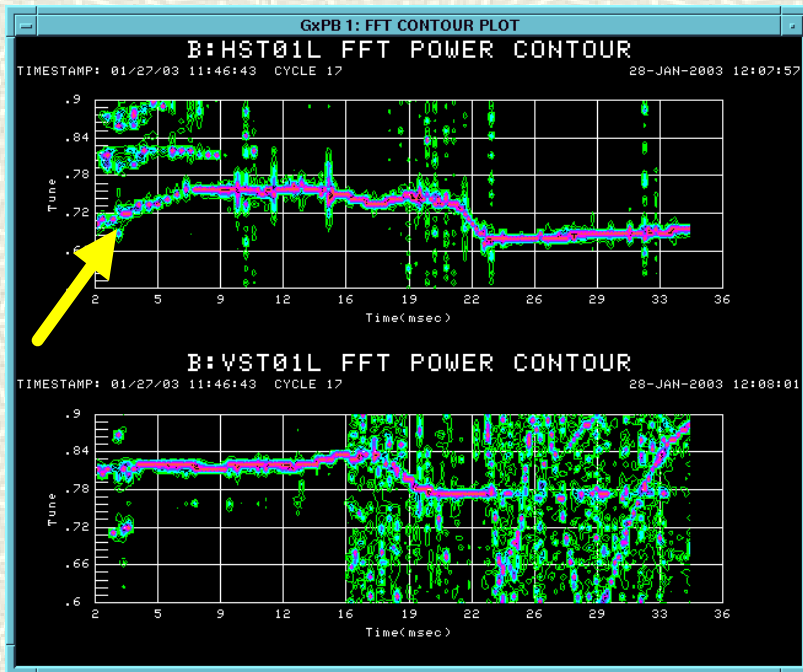


Tune Shift from Dog Leg Change



Dog Legs Nominal

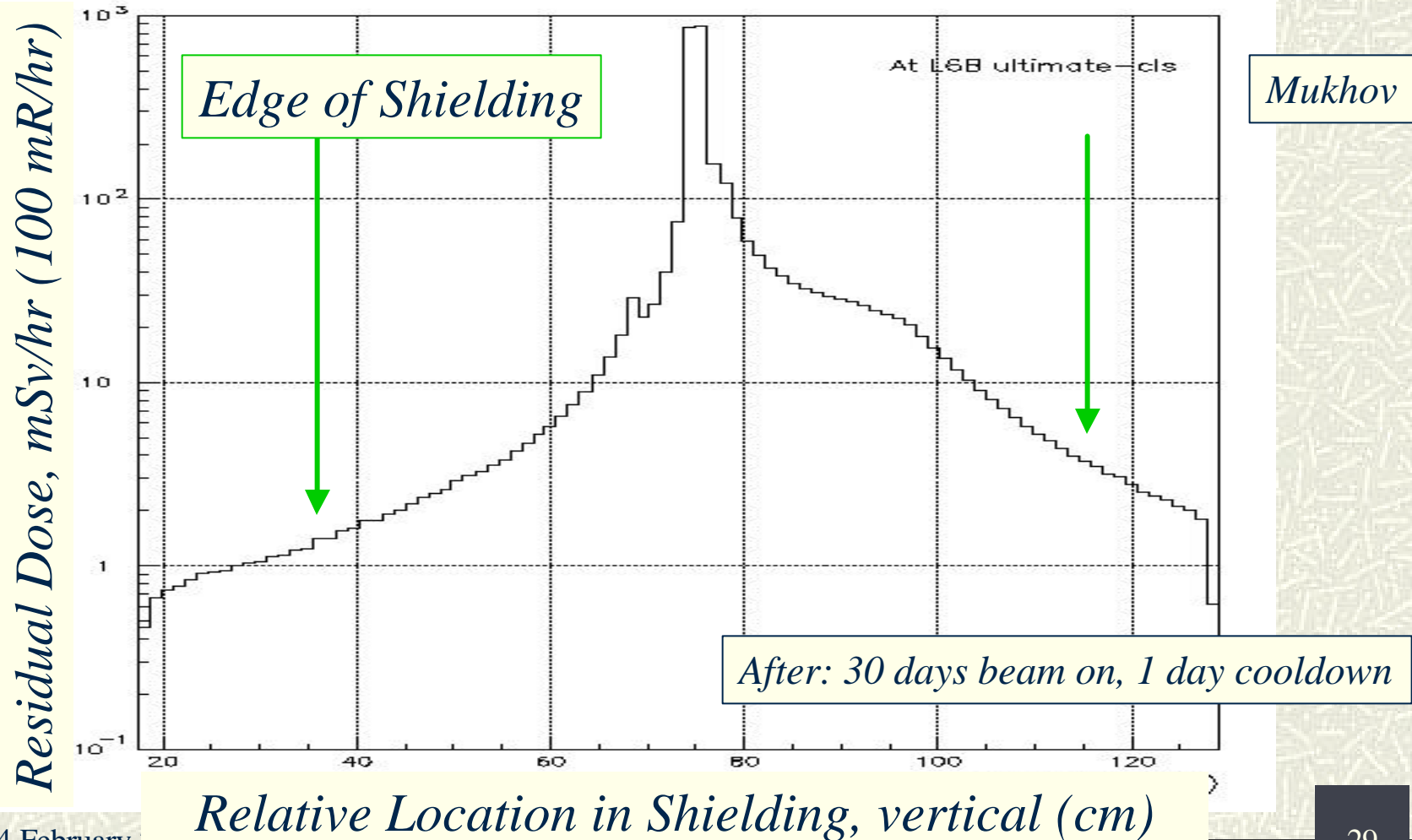
Dog Legs down 40%



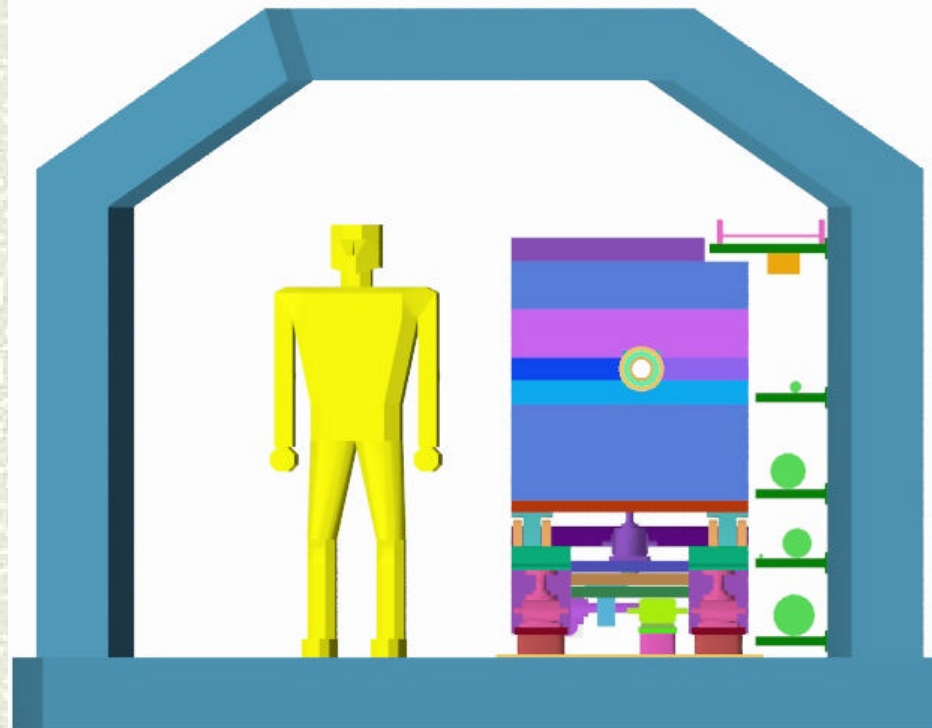
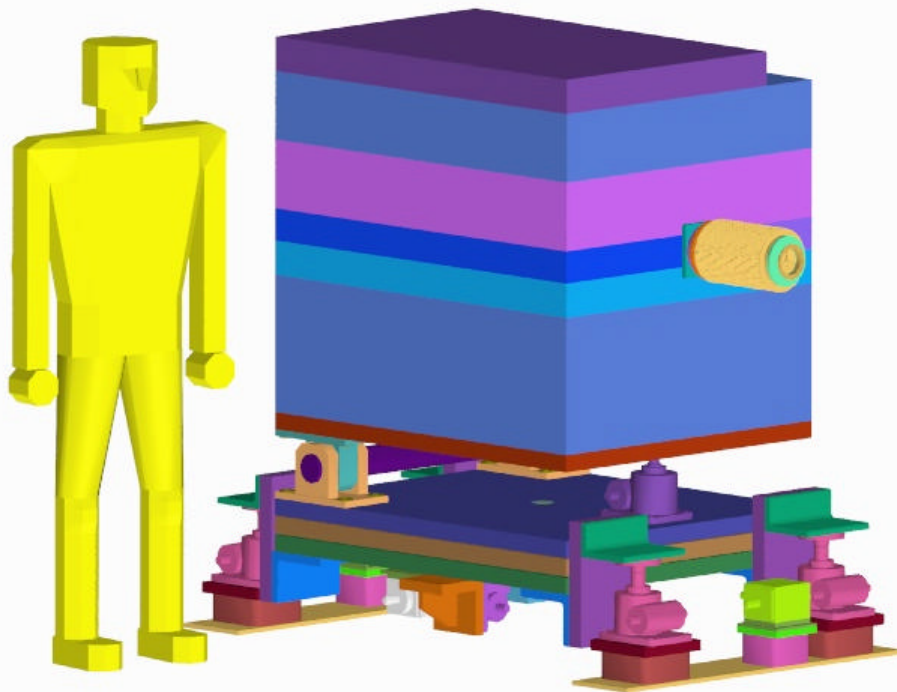
MARS Estimates of Collimator Shielding Activation



Mukhov



Mechanical Design for Collimator Shielding



Design from Larry Bartoszek

Current Issues: Administrative



■ Staffing.

- *Short-term staffing problem: How to use our new workers!*
- *Further needs:*
 - Another technician in Booster to support new engineer.
 - Backup for Lackey already approved, but individual not identified.
 - Coordination of offers of help from MiniBooNE and NUMI.
 - More needs will be determined as new workers gain perspective.

■ Complete and cogent plan for studies.

- *Coordination and direction of all Booster studies (Ankebrandt, Prebys).*
 - Weekly meetings.
- *Understanding space-charge forces on the beam (Chou).*
 - Weekly meetings.

Plans for the Next 8 Months.



- # New Linac power amplifiers
 - *8 scheduled for delivery between now and August*
- # Improvements in the longitudinal dampers system
- # Implementation of transition jump
- # Gradual replacement of aged 400 MeV line power supplies
- # Installation and commissioning of collimator shielding
 - *Want to install before July shutdown*

Plans for July Shutdown



- # Install & commission new 400 MeV Lamberton magnet
- # Installation and commissioning of new 8 GeV EDWA magnets
- # Work on RF cavity upgrade: prototypes installed?
 - *Now, possibly install during July shutdown*

Summary: Proton Source



- # Steady operation for Collider
- # Operating for MiniBooNE
 - *But they want 5X increase in flux*
- # Extensive, dynamic and growing team: investigating Booster issues
- # Worries:
 - *Linac power amplifiers*
 - *Booster activation*
 - Component damage?
 - NUMI turn on before MiniBooNE is finished?!
 - *32 year old machines*
 - And some workers nearing retirement